Mapping Shorelines in Puget Sound III: Management Applications for Inventory and Monitoring

Helen D. Berry and Thomas F. Mumford, Jr.
Washington Department of Natural Resources, Aquatic Resources Division, Nearshore Habitat Program

G. Carl Schoch
Oregon State University, College of Oceanographic and Atmospheric Sciences

Megan N. Dethier
University of Washington, Friday Harbor Labs

Introduction

Nearshore habitat degradation and loss are recognized to be major threats to the health of Puget Sound (British Columbia/Washington Marine Science Panel, 1994). Inventory data is needed to characterize the quantity, location, and quality of habitats, and to guide land use planning. Information on trends in habitat health is needed to identify the habitat features and functions that are most at risk, and to relate these changes to the state of the Puget Sound ecosystem.

The Nearshore Habitat component of the Puget Sound Ambient Monitoring Program (PSAMP) has the dual goals of inventorying nearshore habitat and monitoring trends in health. For the purpose of the monitoring program, nearshore habitat includes the physical and biotic components of intertidal and shallow subtidal areas. Monitoring habitat is a challenge due to the size and complexity of the study area, which includes approximately 2,400 miles of shoreline east of Cape Flattery, and encompasses a wide range of habitats, from vertical rocky shores to wide, protected mudflats. Human activities range from intensive in the highly industrial urban embayments to relatively minor in the least developed areas.

The Nearshore Habitat Program inventories nearshore vegetation by collecting and classifying multispectral sensor data, and inventories other shoreline characteristics using field surveys in conjunction with photo interpretation. At current funding levels, Sound-wide mapping will be completed within 15–20 years. A PSAMP review in 1995 recommended examining alternative methods to map resources Sound-wide in less than five years (Shen, 1995). Additionally, it recommended initiating a program to monitor trends in nearshore habitat health. This paper responds to the recommendations. It reviews user needs, how current systems fulfill user needs, and how inventory methods are being changed in response. It then reviews results of research that tested the feasibility of using a linked geophysical mapping and biota sampling model for inventory and monitoring called SCALE (Shoreline Classification and Landscape Extrapolation).

User Needs

Inventory Information Needs

The Nearshore Program identified two general uses of habitat information, based on information requests: summary resource information for decision making and data for analysis. Summary information needs to address regulations regarding tidal areas, and to be accessible to non-specialists. Commonly, summary information is needed for a specific area of interest to support a permitting or planning decision by a planner, habitat manager, lease manager, or permit reviewer. Information is needed on intertidal zone location, landform type, substrate type, and vegetation present, along with information about critical areas utilized by valued or protected species. According to the Habitat Loss Work Group findings, Sound-wide coverage is needed in a relatively rapid time frame and polygon-based mapping is preferred, similar in format to the now outdated Coastal Zone Atlas (Washington Nearshore Habitat Loss Work Group, 1998).

Summary information needs to be in paper format because many users lack the hardware, software, expertise, or time to use a Geographical Information System (GIS). Many resource managers are unable to use digital data, including those at the Department of Natural Resources and the Washington Department of Fish and Wildlife. Similar experiences have been reported at the local level. The Washington Sea Grant Program found that 83% of local planners do not have the capability to display GIS maps (Goodwin, 1997). Paper map production would increase data distribution costs significantly.

Another set of users needs data with higher spatial resolution and more precise classification categories. Their projects analyze habitat abundance, distribution, quality, and suitability for different species of interest. Digital information is required for area calculation and integration with other data sets. Examples of information requests that we currently receive and we feel detailed mapping would address, include:

- Landscape- or watershed-scale shoreline planning at the local and state level, and review of these plans;
- Habitat assessment modeling in restoration projects. Current examples of projects that could utilize detailed mapping include the habitat analysis projects in Commencement Bay and the Nisqually Wildlife Refuge;
- Oil spill response and damage assessment or other disaster management;
- Analysis of proposed large-scale developments, such as the proposed Cherry Point industrial park, or the Army Corps of Engineers Lummi Road Dike Project;
- Identification of invertebrate and vegetation communities that support food-web interactions or reflect pristine or degraded conditions;
- Comparison of degraded sites to nearby un-impacted areas;
- Identification of resource-rich areas for preservation; and
- Identification of potential habitat for species of interest.

Trends Monitoring Needs

The general goal of long-term monitoring is to provide a statistical baseline from which change can be detected. However, the dynamic nature of the marine environment causes high spatial and temporal variation in organism abundance and community structure. Two common problems arise. First, many monitoring and impact detection programs have confounded spatial and temporal variation by assuming that change has occurred at an impacted site because it is different from a control site, when really the sites were not adequately matched (Schmitt and Osenberg, 1996). Second, results often need to be generalized from specific sites to a large area.

The PSAMP Management Committee has outlined basic requirements for its monitoring programs. Monitoring must measure valued ecosystem components in a cost-effective manner, be meaningful to the public, and link to management activities. The conceptual model of Puget Sound identifies broad questions about habitat to be addressed (Redman, 1996):

- How is the condition of Puget Sound biota correlated with environmental or food web stresses? Biotic habitats of special concern include marine vegetation such as kelp and eelgrass beds and biotic communities that support valued or protected species.
- How is the quantity and quality of the ambient physical environment correlated with Puget Sound's biological communities and functions? Priority issues include the effect of shoreline alteration and changes in water quality on habitats and the species they support.

Inventory and Monitoring Systems

Current Inventory Systems

Two shoreline classification systems are currently used in Puget Sound for general-purpose shoreline inventory. "A Marine and Estuarine Classification System for Washington State" (Dethier, 1990) is used by the Nearshore Habitat Program in the Department of Natural Resources. The Washington Department of Fish and Wildlife uses "The British Columbia Shore-Zone Mapping System" for oil spill response planning (Harper et al., 1991; Howes, 1994).

A Marine and Estuarine Classification System for Washington State is based on the National Wetlands Inventory (Cowardin et al., 1979), with modifications specific to marine and estuarine areas. Data is collected in the field on aerial photographs, then overlayed onto orthophotographs and digitized. Final information includes polygons representing marine or estuarine region, wave/current energy, intertidal or backshore elevation, and substrate type. Substrate information is the most detailed. The minimum mapping unit is approximately 0.5 acres. For a description of methods see Berry and Ritter (1997).

The Nearshore Habitat Program maps nearshore vegetation types by classifying multispectral sensor data. Eight nearshore vegetation types are included: eelgrass, kelp, salt marsh, green algae, red algae, brown algae, mixed algae, and spit/berm vegetation. Resolution is 4 meters. For a description of methods see Berry and Ritter (1997).

Using current methods, the Nearshore Habitat Program could map all intertidal areas in Puget Sound in 15–20 years. Users have indicated that this schedule is not rapid enough, and have recommended examining alternative systems (Washington Nearshore Habitat Loss Workgroup, 1998).

The British Columbia Shore-Zone Mapping System was designed to summarize coastal features for oil spill response planning. The system describes a variety of shoreline characteristics including substrate type, landform, shoreline type, and vegetation. The BC Shore-Zone Mapping System differs from The Marine and Estuarine System primarily in its data format. Rather than delineating polygons, a line is drawn along the shoreline and data tables containing information are attached to segments of the line. The line-based data format produces imprecise area calculations, and is harder to use. However, the collection system is much more rapid. With current funding, the Nearshore Habitat Program could complete Sound-wide mapping in approximately five years.

We are currently evaluating inventory information created using the BC Shore-Zone Mapping System. We are also working with state and local representatives and the Habitat Loss Workgroup to see if the data fulfills user needs. If the more rapid schedule is worth the tradeoff in information format, we will adopt it for Sound-wide mapping.

Potential for SCALE to Fill Gaps in Current Systems

Both of the currently used classification systems fulfill summary information needs. However, both have limited ability to provide detailed information about the quality of different habitats and their resident macro-invertebrate and vegetation communities. A Marine and Estuarine Classification System for Washington State provides the most information with its diagnostic and common species lists, but they are general and not quantitative. This severely limits the degree to which these systems can be used to assess habitat function through community analysis or site comparison. The classification categories are too broad.

The SCALE system was designed to address the limitations of existing systems through its high spatial resolution and its quantification of factors that are known to impact the distribution of biota (Schoch and Dethier, 1996). In summer 1997, we tested the feasibility of using the linked geophysical mapping and biota-sampling model for inventory and monitoring. The SCALE system was initially developed in rocky environments. Our study applied SCALE in soft sediment environments in Carr Inlet, southern Puget Sound. We examined the potential usefulness of the SCALE system in meeting the PSAMP Nearshore Habitat Program goals of inventorying and monitoring habitat. Methods and results of the research are described in Schoch & Dethier (1997), Schoch & Dethier (1998), and Dethier & Schoch (1998). This section integrates results and conclusions of their research with our own analysis of implications with respect to Nearshore Habitat Program objectives.

The strength of SCALE is that mapping methods are linked to a model for habitat clustering, biota sampling, and community extrapolation. The geophysical data is used to statistically cluster shoreline segments into groups of similar habitat types. Segments are then randomly selected from each group and sampled with quadrats and cores to collect quantitative data on vegetation and macro-invertebrate biota. Sampling results about the abundance and frequency of biota at representative beaches can then be extrapolated to other similar segments with known variation statistics, providing users with quantitative information on the frequency and abundance of vegetation and macro-invertebrates.

The geophysical mapping is designed to nest within less detailed classification systems in order to generalize results over large areas. The highest resolution units are alongshore segments of shoreline of 10 meters or longer, divided into intertidal polygons. Alongshore segments are then grouped into blocks based on wave energy, salinity and sea surface temperature. The next successive levels of partitioning are the embayment, district, and region. In addition to generalization over larger geographic areas, shoreline characteristics can be generalized by nesting within the lower resolution Shoreline Type category in the BC Shore-Zone Mapping System.

SCALE is not ideal for summary information uses. It provides more detailed geophysical and biota data than needed and not enough interpreted information. Additionally, SCALE's high resolution mapping is too resource-intensive to meet the requirement of relatively rapid Sound-wide mapping. While SCALE is not ideal for summary information uses, lower resolution systems fulfill user needs for summary information. SCALE would increase the precision of more advanced data analysis because it:

- Allows for analysis of habitat characteristics by intertidal zone;
- Increases the precision of area calculations;
- Provides biotic community information; and
- Provides detailed geophysical characterization for modeling habitat usage by other species.

SCALE potentially fulfills monitoring goals because it characterizes intertidal habitat health, and links to other valued species. Geophysical characteristics and biotic communities that support physical habitat and food web interactions are described. It samples the community of macro-invertebrates and vegetation based on the assumption that the community as a whole is the broadest metric to monitor for changes in health due to multiple stressors. This allows for multivariate analysis of the community, or univariate analysis of species that are valued or are diagnostic of a condition.

Results of the pilot project in Carr Inlet suggest that community information can be generalized by BC Shore-Zone Mapping System Shoreline Type, and by successively increasing spatial scales. This small area result must be further tested to determine if variation in biota is lowered sufficiently for effective trends monitoring, and if results can be generalized meaningfully over large areas by linking to lower resolution mapping systems. If these results are successful, we see a range of potential uses, including:

- Selecting matched sites for field research or applied monitoring to compare regional differences, effects of degradation, etc.;
- Assessing biotic damage following natural or human-caused events;
- Denoting habitats sensitive to oil spills and other disturbances;
- Predicting resource-rich habitats, or those where key resource species could exist; and
- Generalizing results at multiple sites to characterize regional conditions.

SCALE may not meet PSAMP's monitoring goal to provide an easy to understand measure of habitat health. The majority of species surveyed are not valued directly by the public. Because little is known about the life history and population dynamics of many species, preliminary results may provide more information on knowledge gaps than on health trends. An alternative monitoring approach would be to focus on eelgrass, kelp or other vegetation communities that have recognized ecological importance.

We are continuing to evaluate the SCALE system. The current project tests the concept of nesting SCALE with the BC Shore-Zone Mapping Syste*m* by comparing maps created using each system in the same area, and by aggregating the biota data according to the BC Shore-Zone category of Shoreline Type. The next project will collect biota information from three inlets in South Sound in order to see how variation increases over larger areas.

Implications for Trends Monitoring

The SCALE research has helped to focus a series of questions we must answer prior to initiating a monitoring program to assess nearshore habitat health. Future monitoring needs to be driven by priorities that specify species or habitats of interest, the scale of resolution needed, and the scale of variation that can be accepted. Joint consideration of scientific methods and management issues is required to determine what sampling design tradeoffs best answer the highest priority questions with available resources.

Like other large area monitoring efforts, we lack the resources to survey all habitat types at all tidal levels. Underwood and Petraitis (1993) recommend two alternate approaches for addressing this problem: 1) randomize physical habitat features such that sites selected for experiments or monitoring are "properly representative" of all the habitats in a region; or 2) stratify habitats and then replicate studies only within the chosen strata. The advantage of the first approach is that it gives a statistically valid portrait of an area, the disadvantage is in the high variances that will exist among randomly chosen sites due to physical differences. A well-known method for randomizing habitat features in regional monitoring is the Environmental Mapping and Assessment Program (EMAP). For results of data collection using this random stratified design see Bailey et al. (1998). While the second approach lowers variances and increases the ability to detect change, it requires difficult choices about which habitats to study and which to ignore. Certain regions, habitat types, or species of particular concern would need to be identified.

Carr Inlet study results illustrate potential considerations for selecting priority habitat types for sampling. One criterion is habitat abundance. In Carr Inlet, sand and sand-pebble habitats were most abundant. Species richness is another potential criteria. In Carr Inlet, sand habitats had the most species overall, yet had high variability. Gravel and mud habitats had the highest species richness per sample. Selecting the most sensitive habitats would require identification of the stressors of greatest concern. An alternate approach is to census all habitat types, which sacrifices detail, but gains overall coverage. This was the method in Carr Inlet, where mixed coarse, sand, and mud habitats were sampled.

Another variable to consider in sampling design is tidal elevation. We chose intertidal sampling because these communities contain plants and animals that are diverse, productive, and consumed by a variety of species, including humans. At the interface between land and water, these communitites are directly affected by multiple terrestrial and marine stressors. In addition, they are relatively easy to quantify compared to subtidal communities that require more expensive sampling methods such as scuba diving or remote sensing. Within the intertidal zone, the lower intertidal (sampled at mean lower low water) had the most biomass, yielding the most information per sample. While middle and upper intertidal samples had relatively fewer species, these areas are most directly impacted by recognized threats, including oil spill persistence and shoreline modification. Subtidal sampling is desirable, but the increased sampling costs would require further narrowing of habitat types or regions to be monitored.

The number and size of quadrats, cores and sieves is another tradeoff. Concurrent use of quadrats and cores and 2.0-mmsieves generally worked well for capturing the community of surface-dwelling and infaunal species. Greater sample sizes would better quantify very patchy species. Decreasing the sieve mesh size would retain more species, and would be compatible with the 1-mm subtidal sampling methods of the Puget Sound Estuarine Protocol. However, estimates predict than the higher resolution would lead to a 50–100% increase in field sorting and laboratory time. Core diameter and depth was not designed to sample clam densities. Common sense and qualitative comparison to other surveys suggests that larger and deeper-dwelling species, such as clams, are under-sampled using this method. However, larger, deeper cores would require an increase in sorting and identification time required.

Funding is an important factor that will limit the range and number of habitats that are monitored. While the Nearshore Program has resources to fund this work, cooperative research with other groups who need habitat inventory and trends monitoring information would increase its scope.

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